ABNORMALLY COLD TROPOPAUSE TEMPERATURES IN THE EQUATORIAL PACIFIC

C. L. JORDAN

Department of Meteorology, Florida State University, Tallahassee, Fla.
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ABSTRACT

Radiosonde observations made at Kusaie in the eastern Caroline Islands on May 15–16, 1956, reported tropopause temperatures colder than −86° C. in several instances with an extreme value of −96° C. This series of soundings is examined and compared with those made at other stations in the equatorial Pacific area.

In a recent issue of the *Monthly Weather Review*, Stepanova [1] presented a study of minimum temperatures in the lower stratosphere utilizing data taken throughout the world. The well-known meteorograph observation from Batavia, Java made in 1913 [2] was presented to illustrate the extremely cold tropopause temperatures which occasionally occur in the equatorial regions. Stepanova noted that tropopause temperatures lower than the Batavia minimum −90.9° C. have been reported in equatorial regions in recent years but presented no details of these extreme soundings.

The purpose of this note is to present data for an occurrence of abnormally cold tropopause temperatures observed in the central Pacific during May 1956. The data to be discussed were taken by stations in the aerological network established in support of Operation Redwing [1] (fig. 1) and appear in the summaries for the individual stations prepared by Joint Task Force Seven [3]. The upper-air temperature data presented in these summaries are given to the nearest whole degree Celsius. However, in the two cases to be discussed in detail, copies of the original adiabatic charts (WBAN Forms 31A–B) were obtained from the National Weather Records Center.

During the Northern Hemisphere spring months, the tropopause in the Marshall and Caroline Island areas is usually found between 90 mb. and 100 mb. at temperatures near −80° C. In these areas departures of tropopause temperatures in excess of 5° C. from this value are fairly rare. However, during two periods in May 1956 the tropopause temperatures at stations in the network shown in figure 1 were considerably colder than −80° C. The first occurence was during the first few days of the month when Tarawa, Majuro, Kusaie, Ponape, and Kapingamarangi all reported minimum tropopause temperatures as low as −86° C. with an extreme value of −89° C. at

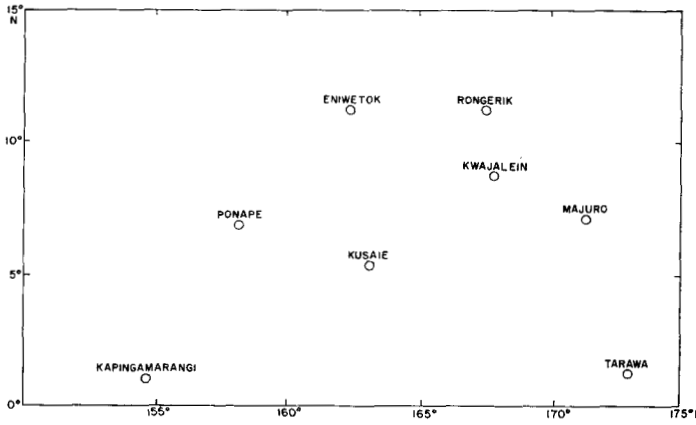

FIGURE 1.—Locater map for upper air stations in the *Operation Redwing* observational program, March–July, 1956.

Tarawa. A second period of low temperatures occurred near the middle of the month, but in this case the abnormally cold values were found primarily at Kusaie. A single report of −90° C. from Tarawa at 17–09 [2] does not appear realistic in view of earlier and later observations. Temperatures as low as −86° and −87° C. were, however, reported at Rongerik and Majuro. At Kusaie, temperatures colder than −85° C. were recorded between 100 mb. and 85 mb. on 12 soundings made during the period from 15–03 to 17–09 (fig. 2). In several other cases during this period, the soundings terminated before reaching temperatures of −85° C. or the tropopause. The coldest temperatures of −96.0° and −92.8° C. were reported by instruments released at approximately 15–18 and 16–08 (table 1). In these cases, the tropopause was reported at heights slightly greater than 17 km. at pressures of 87 mb. and 89 mb. All soundings made between the extreme cases (15–21, 16–00, 16–03, and 16–06) (fig. 2) failed to reach the tropopause, although three of these observations

[1] Redwing is the code name for the United States 1956 atomic test series at the Pacific Proving Ground.

[2] 0900 GMT, May 17, 1956. This notation will be used hereafter for indicating date and Greenwich hours of the observations discussed.

TABLE 1.—*Pressure-height, temperature, and dew point data for all mandatory and significant levels for the two soundings at Kusaie (5°20′ N., 163°01′ E.) on May 15 and 16, 1956 which showed the coldest tropopause temperatures*

1830 GMT, 15 May				0800 GMT, 16 May			
Pressure (mb.)	Height (meters)	Temperature (° C.)	Dew point (° C.)	Pressure (mb.)	Height (meters)	Temperature (° C.)	Dew point (° C.)
1007	7	25.0	23.4	1009	7	27.0	23.7
1000	64	24.5	22.6	1000	82	26.2	23.1
989		23.7	22.0	944		21.6	20.0
850	1,481	18.8	15.8	850	1,494	18.4	14.4
818		17.5	14.6	822		17.4	11.7
700	3,132	10.4	9.0	743		14.5	7.7
665		8.3	7.4	700	3,143	9.9	6.3
640		4.9	3.0	681		7.9	5.4
628		5.4	3.2	516		−3.2	−4.9
590		2.0	0.4	500	5,867	−4.0	−9.7
569		3.0	2.0	495		−4.5	−13.7
537		0.0	−1.3	486		−5.5	−16.3
518		−4.8	−8.4	472		−6.3	−13.4
502		−4.6	−16.0	436		−11.7	−17.5
500	5,867	−4.5	−15.9	420		−12.7	−27.0
482		−6.4	−20.0	400	7,588	−15.7	−25.4
438		−11.6	−16.7	394		−15.2	−20.3
400	7,588	−15.5	−20.9	300	9,700	−30.5	−33.0
342		−23.5	MB	287		−32.9	−34.9
328		−25.7	−37.6	257		−39.3	−40.8
300	9,696	−31.0	−40.1	219		−49.6	
264		−38.7	−45.2	200	12,446	−55.1	
216		−51.0		166		−67.1	
200	12,429	−55.5		150	14,212	−70.8	
174		−62.7		129		−76.3	
150	14,199	−69.3		104		−88.6	
127		−76.0		100	16,510	−89.8	
100	16,510	−88.9		89	17,150	−92.8	
87	17,270	−96.0		77		−71.5	
70		−73.6		75		−71.6	
61		−65.4		59		−73.4	
50	20,472	−68.8		58		−67.7	
48		−69.6		50	20,501	−66.1	
40		−58.5		38		−63.0	
32		−60.7		28			
25	24,839	−53.5				−58.5	
23		−51.0					
18		−47.9					

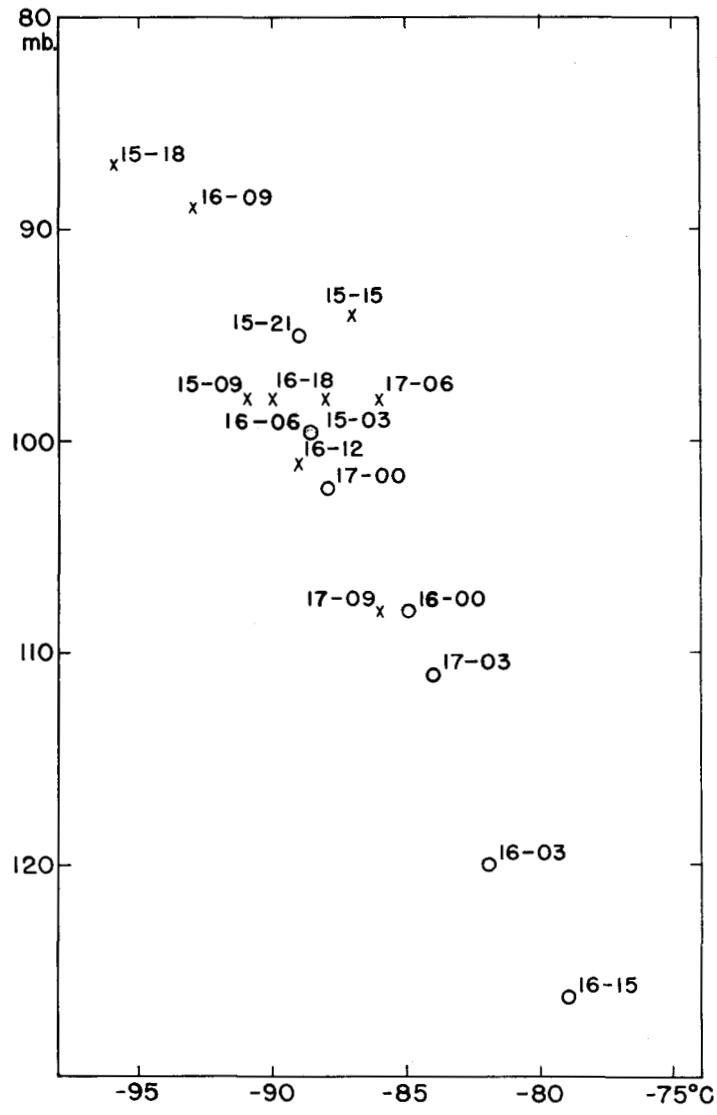

FIGURE 2.—A plot of minimum temperatures indicated by the soundings made at Kusaie during the period from 0300 GMT, May 15, 1956 (15–03), through 0900 GMT, May 17, 1956 (17–09). The values indicated by circles represent soundings which did not ascend above the pressure level at which the value is plotted; those represented by crosses penetrated the tropopause at the pressure level plotted on the diagram.

were made in daylight and special balloons designed for penetration of the tropical tropopause were being used [3]. The earlier of the two extreme soundings was made during the night but the later one was released at 0530 local time and would have been in sunlight at the time the lowest temperature was reported.

The portions of the two extreme soundings between the 300-mb. and the 40-mb. levels are shown in figures 3 and 4 along with soundings made at or near the same time at other stations in the network. Soundings at the same time were not available in several cases because other stations were also having difficulties in getting balloons through the abnormally cold tropopause. Temperatures at Kusaie were appreciably colder in the layer between 110 mb. and 80 mb. than those indicated at other stations. However, temperature differences were quite negligible at levels below 200 mb. and above 60 mb. (figs. 3 and 4). This agreement at the lower and higher levels offers strong evidence that the extremely cold temperatures reported at Kusaie did not arise from large systematic errors of the type occasionally found in radiosonde observations. Of course, instrumental and evaluation errors may have been present and at these very low values the temperature resolution is not very great. The smallest unit used in the evaluation procedure (0.1 recorder division) corresponds to about 0.6° C. at temperatures in the vicinity of −90° C. However, in view of the consistency of the extreme observations with those made earlier and later (fig. 2) and the fact that the upper and lower portions of the extreme soundings agree with those for the other stations (figs. 3 and 4), it is felt that errors probably did not exceed 1°–2° C.

The minimum tropopause temperatures at other stations in the network were appreciably higher during the May 15–17 period than those reported at Kusaie. At Ponape and Kwajalein, the stations closest to Kusaie, the tropopause was reported between 80 mb. and 90 mb. in several cases but temperatures were not reported colder than −84° C. Observations were being made at 6-hour intervals at Ponape and at 12-hour intervals at Kwajalein

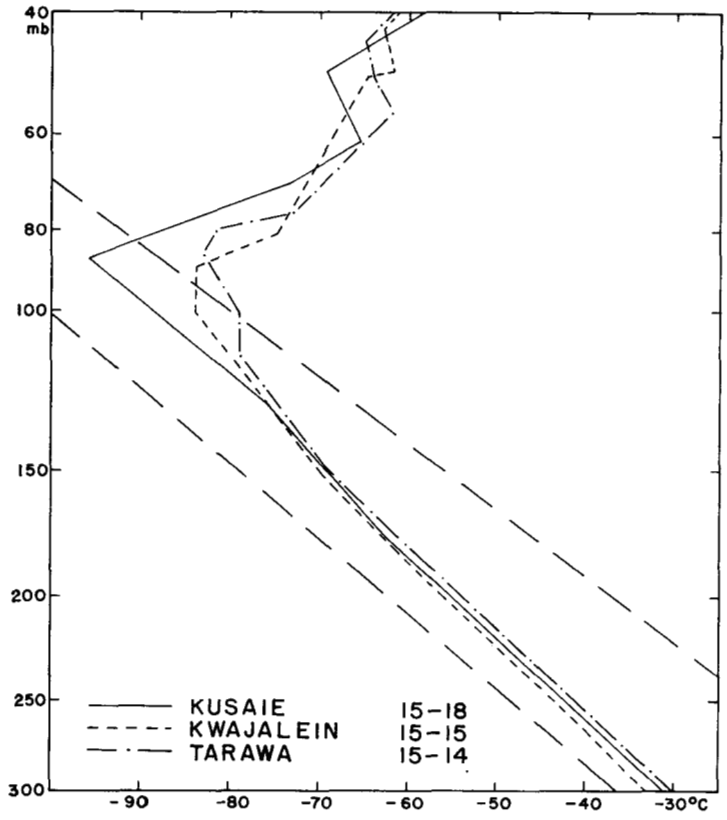

FIGURE 3.—A plot of a portion of the sounding made at Kusaie at 1830 GMT, May 15, 1956 (solid), showing an abnormally cold tropopause temperature. Soundings made near the same time at Kwajalein and Tarawa are also shown. The sloping straight lines are dry adiabats.

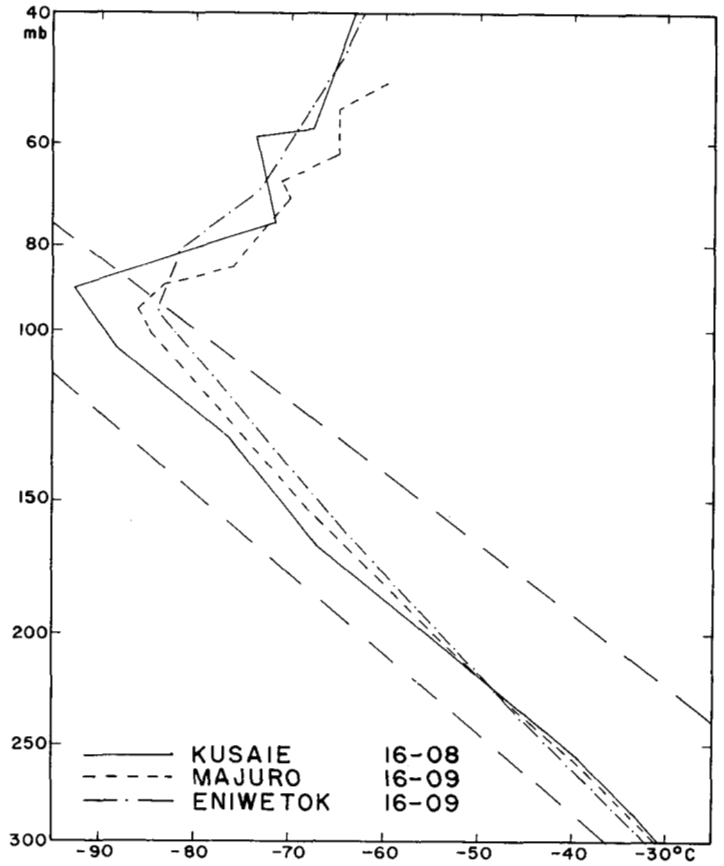

FIGURE 4.—A plot of a portion of the sounding made at Kusaie at 0800 GMT, May 16, 1956 (solid), showing an abnormally cold tropopause temperature. Soundings made near the same time at Majuro and Eniwetok are also shown. The sloping straight lines are dry adiabats.

during the period of primary interest. The coldest tropopause temperatures observed at Rongerik during the Redwing observation period (−85° C. and −86° C.) were reported at 16–15 and 17–03. Presumably some of the cold air from the vicinity of Kusaie could have passed Kwajalein undetected between 15–15 and 16–15 since the only sounding made during this period failed to reach the tropopause. Although the observations mentioned above fail to show strong evidence for an extensive area of abnormally cold air at the tropopause level, it is felt that the consistency of the observations from Kusaie is such that it would be difficult to discount the very cold temperatures reported at 15–18 and 16–08. The lowest temperatures coincided with the greatest reported tropopause heights (fig. 2) which might suggest that the cold temperatures resulted from unusual convective activity.

The weather appears to have been disturbed at Kusaie during the period of coldest tropopause temperatures. A stratocumulus overcast at heights of 1,000–2,000 ft. was reported on all except one of the 3-hourly observations between 15–03 and 16–18. Rain was reported in present weather only at 16–06 but past rain and rain within sight was reported on all observations between 15–15 and 16–06. The total rainfall during the 15th and 16th was over 2 inches but rainfalls of this magnitude are fairly common at Kusaie. The island is mountainous with a maximum elevation of about 2,000 ft. and has an annual rainfall of 200–300 inches.

Most of the rainfall at Kusaie during the 15th and 16th occurred during the two 6-hour periods immediately preceding the coldest soundings. A total of 1.09 inches fell in the period from 15–12 to 15–18 and 0.77 inches in the period from 16–00 to 16–06. During the periods of heaviest rain, the low-level winds at Kusaie were from the east and light. Speeds shown on the 3-hourly observations did not exceed 5 knots at the surface and were less than 20 knots in the lowest 10,000 ft. of the atmosphere. Beginning at about 16–03, the wind speeds began to increase and the winds shifted to the southeast. Speeds in the 3,000–7,000-ft. level attained values in excess of 25 knots on three successive observations with a maximum reported speed of 36 knots. The rain had ended by 16–09, near the time of strongest low-level wind speeds, and no additional rain was reported on the 16th or 17th.

The protracted period of rain and low ceilings and the shift of the wind from east to southeast at Kusaie clearly

suggest the passage of the equatorial convergence zone to the north of the station. Additional evidence was provided by the low-level portion of the ROC BRAVO reconnaissance flight made on May 15–16 [3]. This flight showed a pronounced wind shift from east to southeast at the 1,500-ft. level in passing through a weather area 100–200 miles east and southeast of Kusaie at about 16–00. The same type of cloudiness was reported as at Kusaie, especially to the north of the wind shift line, and for short periods the aircraft was in continuous cloud at the 1,500-ft. level. The low-level wind observations from Majuro and Tarawa suggest that the equatorial convergence zone was located between these stations during May 15–17. The weather was good at Tarawa on the south side of this zone but rain was heavy at Majuro and also at Jaluit, which is located about 125 miles southwest of Majuro. At both these atolls rainfall exceeded 5 inches during the 3-day period. Most of the rain at Majuro fell between 16–18 and 17–00 with a total accumulation of 4.04 inches during this period.

At middle tropospheric levels, Kusaie was on the west side of a well-developed anticyclonic circulation on the 15th and the center of this system passed the station at about 16–08. The upper tropospheric flow was generally westerly at all stations in the network during the early part of the period of interest with speeds at the 200-mb. and 150-mb. levels in excess of 50 knots at the northernmost stations. Speeds decreased during the 15th but at the 100-mb. and 150-mb. levels the winds retained a westerly component throughout the 16th at all stations, except for short periods at Kapingamarangi, Kusaie, and Kwajalein. It appears likely that the disturbed flow at the 40,000 to 55,000-ft. levels at Kusaie and Kwajalein during the 16th was associated with the area of cold air detected over Kusaie. From a preliminary examination of the upper tropospheric wind data at several stations, it would appear that, despite the low latitudes, the geostrophic thermal wind relationship could be used in tracing an area of cold air from the vicinity of Kusaie to the north or northeast of Kwajalein.

The weather conditions and circulation patterns during May 15–17 actually offer little or no information which could be used in substantiating the abnormally cold temperatures reported in the upper troposphere over Kusaie. It is interesting, however, that the equatorial convergence zone was located near the station, and apparently was well-developed, at the time the coldest and highest tropopauses were reported.

Addendum: Following the preparation of this note, the author has examined some upper-air records which suggest that the mean tropopause temperatures in the dry zone of the central equatorial region to the south of the Hawaiian Islands are somewhat colder than those observed over the Marshall and Caroline Islands. Data taken at Christmas and Malden Islands during the British nuclear tests in early 1957 reported mean monthly temperatures of −85° to −88° C. During the period from 1400 GMT, February 19, through 0200 GMT, February 22, 1957, there were five successive observations at Malden Island which reported tropopause temperatures colder than −92° C. An extreme value of −99° C. was reported on a daytime sounding made during this period.

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